Dielectric Response of "Diamondlike" Carbon Films Prepared by rf Plasma Deposition

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Introduction

The so called "Diamondlike" carbon (DLC) films are transparent in much of the visible, are hard (up to 9 on a MHO's scale), and resistant to chemical attack. These films exhibit low electrical interface state densities when deposited on silicon and indium phosphide. Thus they are of interest for potential use as both gate and field dielectrics in high speed integrated circuits. An important practical question then is how good are these films as dielectrics?

Experiments and Samples

DLC films have been prepared from rf plasma deposition onto metal substrates. Small area metal dots are then deposited by evaporation through masks onto the top surface. Thus Metal-Insulator-Metal (MIM) structures were formed which were used to study dielectric response in the 10 Hz to 13 MHz frequency range. Both gold and aluminum were used as electrodes, and a Hewlett Packard 4192A LF Impedance Analyzer and desk top computer were used to measure the capacitance and conductance as a function of frequency and voltage.

Results and Discussion

The dependence of the ac conductivity on the dc bias applied across the film was investigated. It is found that dc bias only affects the low frequency portion, which is the result of the dc conductivity changing. The dc bias has little effect of the ac conductivity of these films. The dc conductivity plotted against the square root of the dc electric field applied to the film yields a straight line at higher fields. This is a characteristic of either Frenkel-Poole, or Schottky conduction of electrons in the film. Very careful temperature dependent studies would need to be made to distinguish between these two mechanisms.

At low to midrange frequencies conductance versus frequency data fit a generalized power law dependence, consistent with both dc and hopping conduction components. At higher frequency a spurious square law dependence of conductance on frequency is found which cannot be explained as due to lead resistance effects. Barrier potential effects may be important in thinner films. The dielectric loss tangent is nearly constant at 0.5 to 1.0% over the range from 1 kHz to 100 kHz, but these values can probably be reduced by optimizing process parameters. The dc resistivity is above 10^{13} ohm-cm, and breakdown strengths above 8×10^{6} v/cm were found. Again, this value for breakdown strength may not be a maximum because of process dependence.